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ACOUSTIC ATTENUATION RESEARCH AT USL.(U)

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NAVY UNDERWATER SOUND LABORATORY
FORT TRUMBULL, NEW LONDON, CONNECTICUT

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Acoustic

ACOUSTIC ATTENUATION RESEARCH AT USL.[1]

[redacted]

by

David G. Browning

USL Project No.
9-A-401-00-00/175

SF 11552 001 11282

USL Technical Memorandum No. 2211-196-68

19 July 1968

8p.

USL-TM-2211-196-68

INTRODUCTION

This paper describes the research which has been done at this Laboratory concerning the attenuation of low-frequency sound in the ocean. By low frequency we mean from 10-10,000 Hz. Starting in the middle 1950's, interest in long-range acoustic systems stimulated low frequency attenuation measurements. The small losses involved at these frequencies require somewhat specialized experimental conditions which are shown in the first figure. In order to get totally refracted acoustic paths over the order of hundreds of miles the so-called sound channel is utilized. By detonating explosive charges at the sound velocity minimum, some of the energy is constrained by the two gradients to travel along the channel axis. The received signals when analyzed, are filtered to give data in a particular frequency band.

LEVEL II

[1] This paper was presented at the 34th Meeting of the Undersea Warfare Research and Development Planning Council, 25-28 June 1968 at the U. S. Navy Underwater Sound Laboratory, Fort Trumbull, New London, Connecticut.

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RESULTS

Experiments of this type which were conducted in the 50's and early 60's, in general, indicated that attenuation was greater than expected, but the real breakthrough did not come until 1965 when William Thorp of this Laboratory published a compilation of the data which showed the magnitude of the anomalous attenuation as shown in Fig. 2. Various authors put forth at least eight different explanations (Fig. 3) none of which appeared to have any obvious physical merit over the others. The last two are more recent and will be mentioned later.

By 1966, more data was available and was in excellent agreement with the trend of the previous results. In light of this, we felt the best thing to do was to obtain a mathematical fit to the data, and from its form, hope to get a clue to the best explanation. The result shown in Fig. 4 was of the form of a chemical relaxation process which instead of eliminating possible explanations, suggested a few more. Fig. 5 shows the entire formula for saltwater. The first term is the anomaly, the second is due to magnesium sulphate and the third to viscosity.

Consultation with chemists indicated that the anomaly might either be caused by dissolved salts or by the water structure itself. The matter could be resolved by comparison with fresh water data. Unfortunately, no such data existed and it appeared impractical to make laboratory measurements at these low frequencies. As a result, in September 1967, we applied our saltwater measurement techniques to the largest fresh water lake in the world, Lake Superior. Fig. 6 shows the path of the experiment. Our results indicate that the anomalous attenuation exists in freshwater also. The actual experimental measurements are shown in Fig. 7, with the resulting formula compared with that of saltwater in Fig. 8.

CONCLUSIONS

Although such a slow relaxation would have been thought impossible for water several years ago, recent experiments for example, those conducted at the University of Florence in Italy indicate that water is perhaps capable of even slower processes. Our experiment does not uniquely determine the cause of attenuation, however, because it is not inconsistent with some of the other explanations. It does tend to eliminate some of them, but we are the first to realize the limitations of a single experiment.

We do feel that we should pursue the idea of a structural relaxation further. Since the Atlantic Ocean where the saltwater measurements were made and Lake Superior were at the same temperature, the crucial test will be to make measurements at a different water temperature and see if we get a shift in the relaxation frequency. In support of this, Leroy's measurements in the Mediterranean (13°C) indicate a relaxation frequency of 1.7 kHz. Fig. 9 shows what the prediction would be for the cases with the greatest difference, Lake Tangankyia (freshwater) and the Red Sea (saltwater). These bodies of water are where we plan to make our next measurements. If there is a shift and we live to tell the tale, we can identify the cause and compute the activation energy of the process.

David Browning

David G. Browning
Physicist

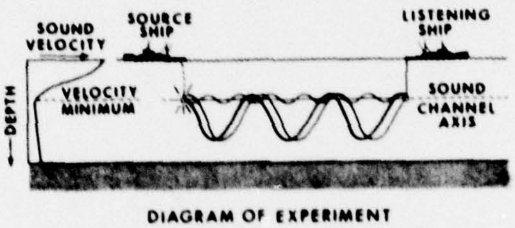
SOUND VELOCITY
SOURCE SHIP
LISTENING SHIP
VELOCITY MINIMUM
SOUND CHANNEL AXIS
DEPTH
DIAGRAM OF EXPERIMENT

FIG. 1

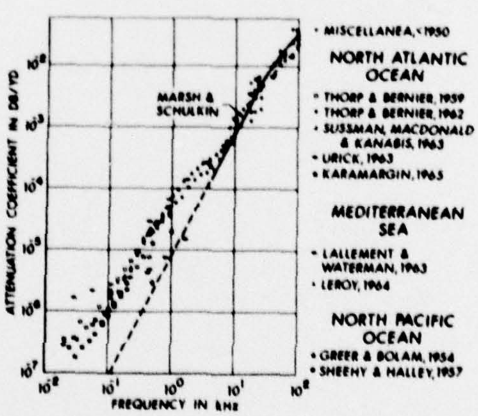
ATTENUATION COEFFICIENT IN DB/YD
FREQUENCY IN kHz
MARSH & SCHULKIN
MISCELLANEA, <1950
NORTH ATLANTIC OCEAN
THORP & BERNIER, 1959
THORP & BERNIER, 1962
SUSSMAN, MACDONALD & KANABIS, 1963
URICK, 1963
KARAMARGIN, 1965
MEDITERRANEAN SEA
LALLEMENT & WATERMAN, 1963
LEROY, 1964
NORTH PACIFIC OCEAN
GREER & BOLAM, 1954
SHEEHY & HALLEY, 1957

FIG. 2

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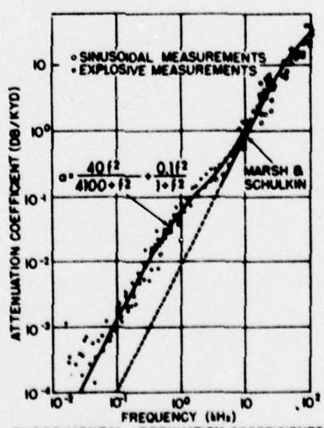
POSSIBLE EXPLANATIONS FOR ATTENUATION ANOMALY

1.	Suspended Matter	Duykers, JASA 41 (67) 1330
2.	Biological Scattering	Weston, JASA 40 (66) 1558
3.	Finite-Amplitude Effects	Marsh, Mellen, Konrad, JASA 38 (65) 326
4.	Inhomogeneities	Urick, JASA 35 (63) 1413
5.	Eddy Viscosity	Schulkin, JASA 35 (63) 253
6.	Channel Leakage	Urick, JASA 35, (63) 1413
7.	Internal Waves	(No calculations)
8.	Relaxation Process (Unknown)	Thorp, JASA 38, (65) 648 Urick, JASA 39 (66) 904 LeRoy, JASA 36 (64) 1014
9.	Relaxation Process - ions	Horne, T.R. 33 ONR
10.	Relaxation Process - water	Browning, Thorp, Mellen - Int. Congress-Tokyo

These references discuss the concepts involved but are not necessarily in support of them.

FIG. 3



EXPERIMENTAL ATTENUATION COEFFICIENTS

FIG. 4

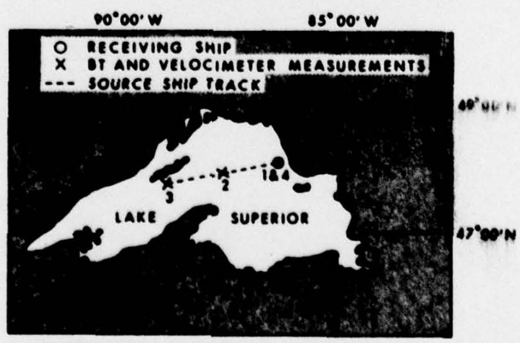
ATTENUATION IN SEAWATER

LOW-FREQUENCY ANOMALY	$MgSO_4$ RELAXATION	VISCOUS ABSORPTION

$$\alpha = \frac{0.1\,f^2}{1+f^2} + \frac{40\,f^2}{4100+f^2} + 0.000275\,f^2$$

α = ATTENUATION IN DB/KYD
f = FREQUENCY IN kHz

FIG. 5



EXPERIMENTAL TRACK (LAKE SUPERIOR)

FIG. 6

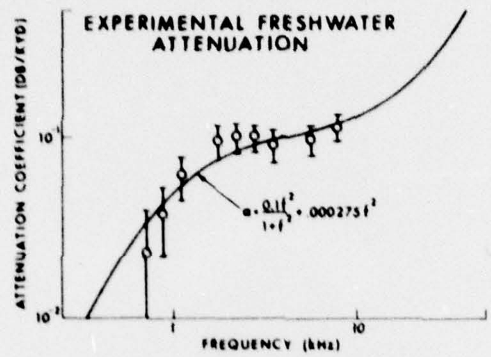


FIG. 7

ATTENUATION IN FRESHWATER

$$\alpha\,(\mathrm{DB/KYD}) = \frac{0.1 f^2}{1 + f^2} + 0.000275\, f^2\,, \quad f\ (\mathrm{kHz})$$

ATTENUATION IN SEAWATER

$$\alpha\,(\mathrm{DB/KYD}) = \frac{0.1 f^2}{1 + f^2} + \frac{40 f^2}{4100 + f^2} + 0.000275\, f^2\,, \quad f\ (\mathrm{kHz})$$

FIG. 8

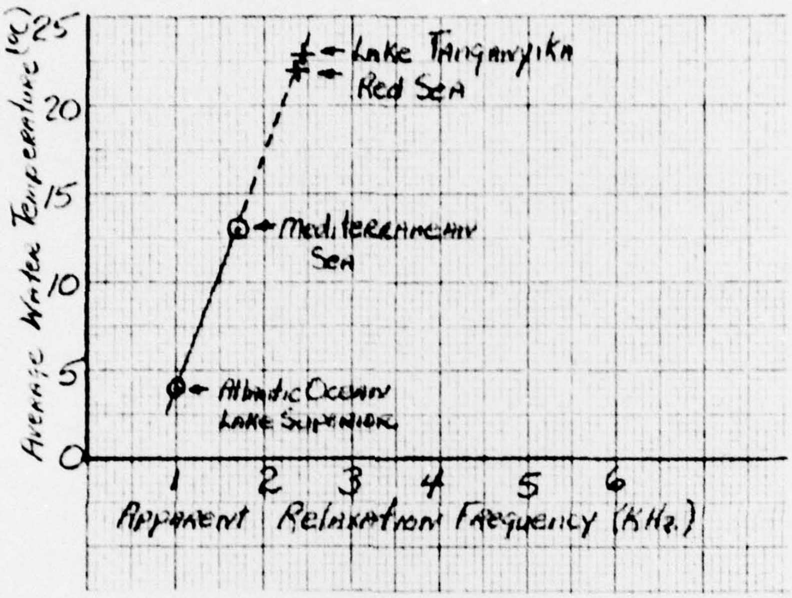

Lake Tanganyika
Red Sea
Mediterranean Sea
Atlantic Ocean
Lake Superior
Average Water Temperature (°C)
0
5
10
15
20
25
1
2
3
4
5
6
Apparent Relaxation Frequency (KHz)

FIG. 9